The Impulse-Momentum Change Theorem

Momentum and Impulse Connection

The term *momentum* is a physics concept. Any object with momentum is going to be hard to stop. To stop such an object, it is necessary to apply a force *against* its motion for a given period of time.

The more momentum which an object has, the harder that it is to stop.
Thus, it would require a greater amount of force or a longer amount of time or both to bring such an object to a halt.
As the force acts upon the object for a given amount of time, the object's velocity is changed; and hence, the object's momentum is changed.

You have also experienced this a multitude of times while driving. As you bring your car to a halt when approaching a stop sign or stoplight, the brakes serve to apply a force to the car for a given amount of time to change the car's momentum. An object with momentum can be stopped if a force is applied *against* it for a given amount of time.

Force acting for a given amount of time will change an object's momentum. Put another way, an unbalanced force always accelerates an object - either speeding it up or slowing it down.

In football, the defensive player applies a force for a given amount of time to stop the momentum of the offensive player with the ball.

- If the force acts opposite the object's motion, it slows the object down.
- If a force acts in the same direction as the object's motion, then the force speeds the object up.
- Either way, a force will change the velocity of an object.
- And if the velocity of the object is changed, then the momentum of the object is changed.

$$F = m * a = m * \frac{\Delta v}{t}$$

or

$$F = m * \frac{\Delta v}{t}$$

If both sides of the above equation are multiplied by the quantity t, a new equation results.

$$F * t = m * \Delta v$$

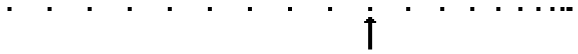
This equation represents one of two primary principles to be used in the analysis of collisions during this unit. To truly understand the equation, it is important to understand its meaning in words. In words, it could be said that the force times the time equals the mass times the change in velocity.

In physics, the quantity Force • time is known as impulse. And since the quantity m•v is the momentum, the quantity m• Δv must be the change in momentum. The equation really says that the
Impulse = Change in momentum

In a collision, an object experiences a force for a specific amount of time which results in a change in momentum. The result of the force acting for the given amount of time is that the object's mass either speeds up or slows down (or changes direction). The impulse experienced by the object equals the change in momentum of the object. In equation form, F • t = m • ∆ v.

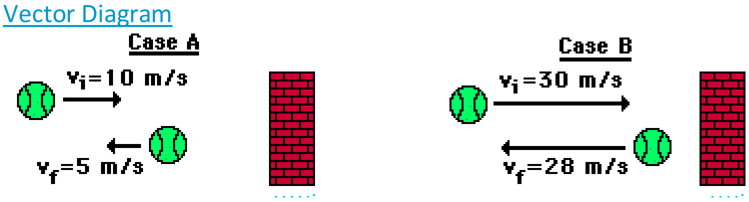
In a collision, objects experience an impulse; the impulse causes and is equal to the change in momentum.

Consider a football halfback running down the football field and encountering a collision with a back. The collision would change the halfback's speed and thus his momentum. If the motion was represented by a ticker tape diagram, it might appear as follows:



Now consider a collision of a tennis ball with a wall. Depending on the physical properties of the ball and wall, the speed at which the ball rebounds from the wall upon colliding with it will vary. The diagrams below depict the changes in velocity of the same ball. For each representation (vector diagram, velocity-time graph, and ticker tape pattern), indicate which case (A or B) has the greatest change in velocity, greatest acceleration, greatest momentum change, and greatest impulse. answer.

Vector Diagram



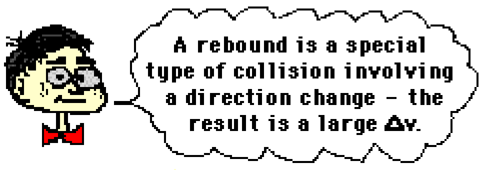
Greatest velocity change?
Greatest acceleration?
Greatest momentum change?
Greatest Impulse?

The velocity change is greatest in **case B**. The velocity changes from +30 m/s to -28 m/s. This is a change of 58 m/s (-) and is greater than in case A (-15 m/s).

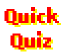
b. The acceleration is greatest in **case B**. Acceleration depends on velocity change and the velocity change is greatest in case B (as stated above)

c. The momentum change is greatest in **case B**. Momentum change depends on velocity change and the velocity change is greatest in case B (as stated above).

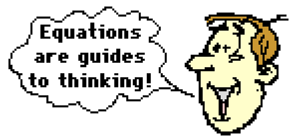
d. The impulse is greatest in **case B**. Impulse equals momentum change and the momentum change is greatest in case B (as stated above).



Observe that each of the collisions above involve the rebound of a ball off a wall. Observe that the greater the *rebound effect*, the greater the acceleration, momentum change, and impulse. A rebound is a special type of collision involving a direction change in addition to a speed change. The result of the direction change is a large velocity change. On occasions in a rebound collision, an object will maintain the same or nearly the same speed as it had before the collision. Collisions in which objects rebound with the same speed (and thus, the same momentum and kinetic energy) as they had prior to the collision are known as elastic collisions. In general, elastic collisions are characterized by a large velocity change, a large momentum change, a large impulse, and a large force.



Use the impulse-momentum change principle to fill in the blanks in the following rows of the table. As you do, keep these three major truths in mind:



the impulse experienced by an object is the force•time
the momentum change of an object is the mass•velocity change
the impulse equals the momentum change

	Force (N)	time (s)	Impulse (N*s)	Mom. Change (kg*m/s)	Mass (kg)	Vel. Change (m/s)
1.		0.010			10	-4
2.		0.100	-40		10	
3.		0.010		-200	50	
4.	-20 000			-200		-8
5.	-200	1.0			50	

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